institute for building efficiency
an initiative of Johnson Controls

REINVENTING EXISTING BUILDINGS: EIGHT STEPS TO NET ZERO ENERGY

Issue Brief

Cara Carmichael
Senior Consultant, Rocky Mountain Institute

Katrina Managan
Program Manager, Institute for Building Efficiency, Johnson Controls

Rocky Mountain Institute®

Johnson Controls

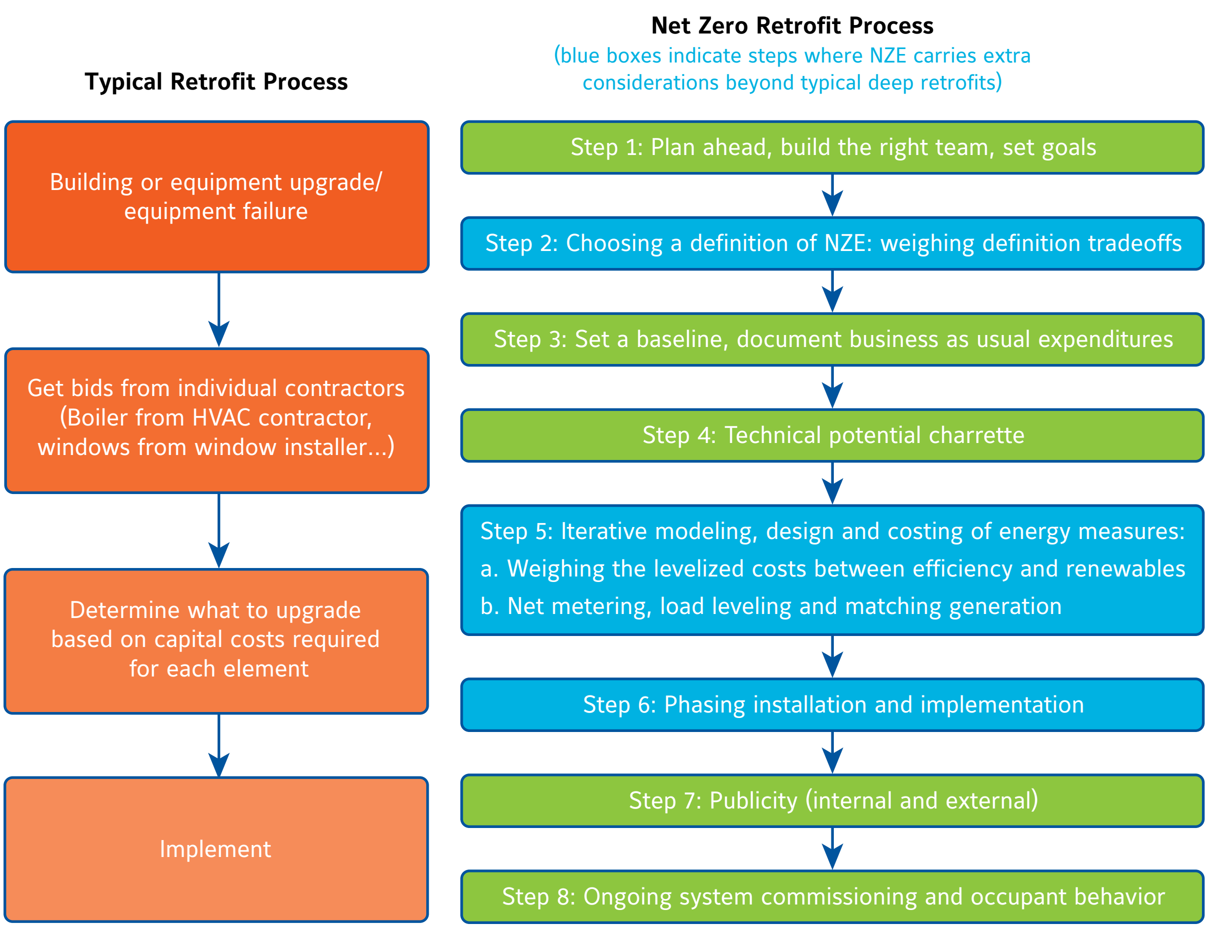
May 2013

INTRODUCTION

Net zero energy describes buildings whose energy consumption and emissions are fully offset by renewable energy, preferably generated on site. True to their net zero name, they generate as much or more clean energy as they consume. Once considered an outlandish, far-reaching, expensive goal only available to the technically advanced, net zero buildings are now well within the realm of possibility. A study by the National Renewable Energy Laboratory found that there is the technical potential for over 47 percent of existing commercial building floor space to achieve net zero energy using currently known technologies and design processes.[1]

Whether focused on new construction or – in this case – existing buildings, designing a net zero energy building involves two fundamental steps: first maximize energy efficiency to minimize the building's demand, then explore renewable energy generation to cover remaining energy needs. To make net zero technically possible and cost-effective, a building needs to reduce typical energy use by well over 50 percent.[2]

Figure 1: Typical retrofit, deep retrofit and net zero retrofit process considerations



[1] Griffith et al. "Assessment of the Technical Potential for Achieving Net Zero-Energy Buildings in the Commercial Sector" National Renewable Energy Laboratory. December 2007.

[2] Nesler et.al. "Absolute ZeroNet Zero Energy commercial buildings – an inspiring vision for today." Institute for Building Efficiency, Johnson Controls.

The process of taking an existing building to net zero energy is similar to that of a deep energy retrofit,[3] with some additional considerations. A deep energy retrofit involves a whole-building analysis process that delivers much larger energy cost savings – sometimes more than 50 percent reduction – and fundamentally enhances the building value.

The following analysis describes the process of completing a net zero retrofit. Figure 1 shows a typical retrofit process contrasted with a deep retrofit process. On the right, in green, the deep retrofit process is shown. The blue steps on the right indicate the additional considerations that need to be taken in a net zero energy project process.

INDUSTRY CONTEXT

Net zero energy has been achieved in a number of new buildings. While more challenging, it has also been done in existing buildings. The primary differences between achieving net zero energy in an existing building are that massing, orientation, site configuration and systems are predetermined and for the most part fixed. Also, existing buildings have facility managers and tenants who have operational expectations and use patterns that may need to change. The effort required to change occupant expectations and behavior, and the potential impact of those changes, should not be underestimated.

Achieving net zero energy is most likely to be feasible in:

- Low-rise buildings (one- or two-story). It becomes exponentially more difficult to achieve net zero energy in buildings with more than two floors due to limited roof area for PV and the use of elevators.
- Moderate climate zones. It is more challenging to achieve net zero energy in extremely humid locations such as Florida or the southern parts of Mississippi, and in extremely cold locations such as North Dakota and the tip of Maine.
- Buildings such as warehouses (nonrefrigerated) and religious worship, retail and education facilities. Offices generally have lower potential to reach net zero, largely due to high plug and process loads and typically tall building massing. In general, size is not a critical factor in determining the likelihood of achieving net zero.
- Buildings with low plug and process loads (i.e., appliances, office equipment, computers).[4]

Case Study: Wayne Aspinall Federal Building and U.S. Courthouse[5]

Location: Grand Junction, Colorado

Size: 41,562 ft^2

The 92-year-old Wayne Aspinall Federal Building and U.S. Courthouse is the country's first net zero energy historic building. After a retrofit completed in early 2013, the building now features energy efficient technologies such as fluorescent lighting with wireless controls and storm windows with a solar film covering that will reduce the heating and cooling demand. A geothermal heating and cooling system, a 115 kW roof- and canopy-mounted photovoltaic system, DC micro-grids and variable refrigerant flow systems were also installed. The project aims to achieve a LEED Platinum certification, and the GSA expects to save roughly $16,000 in annual energy costs and reduce peak energy demand by 125 kW after the renovation is completed.

[3] More information on Deep Energy Retrofits, Rocky Mountain Institute: www.retrofitdepot.org

[4] Griffith et al. "Assessment of the Technical Potential for Achieving Net Zero-Energy Buildings in the Commercial Sector" National Renewable Energy Laboratory. December 2007.

[5] For more information see the General Services Administration website: http://www.gsa.gov/portal/content/121123

These indicators represent the average achievability of net zero based on industrywide analysis. However, this same rule-of-thumb analysis is discouraged in design and should not dissuade a project from attempting to achieve net zero.

STEP 1: PLAN AHEAD, BUILD THE RIGHT TEAM, SET GOALS

The need for a retrofit can be a sudden and not-so-subtle milestone in a building's life, often preceded by the degradation or failure of a key piece of equipment. When equipment fails, it is useful to analyze the life-cycle cost of replacing that equipment, along with complimentary retrofit measures. This can result in a better long-term outcome for the building.

Planning ahead for equipment replacement and starting with the replacement of load reduction measures over time (such as upgrading windows, reducing plug loads, and improving lighting controls) enables better decision-making when equipment fails. Good planning can also help avoid common pitfalls, such as following rules of thumb on sizing and equipment selection based on obsolete data and assumptions that were relevant a generation ago.

Assembling the right execution team helps as well. The team should include designers and engineers who can design across systems and understand whole building benefits, as well as building maintenance personnel and building operators. The right team will also be able identify and mitigate risks that may arise during the project.

The team should gather the energy use and cost data, upgrade history, equipment performance and life expectancy data, capital expenditure forecasts, lease structures, and major lease rollovers (for investor-owned buildings). Working together, the owner and design team can put forth goals that can include achieving net zero energy. The team should start planning early and keep all key stakeholders engaged throughout the process.[6]

To maximize cost-effectiveness, a building should undergo a net zero retrofit when the building is 'ripe' for a retrofit. For example, if one or more major system or structural replacements are already planned, additional energy efficiency measures and renewable energy can be designed in to maximize interactive effects and optimize overall energy use. A building may also be ripe for a net zero retrofit when an owner wants to reposition the building in the market, when an upgrade is needed to meet code, when a major tenant is moving in or out, or as part of portfolio resource planning.[7]

[6] Ghiran and Meyer. "The Move Towards Net Zero Energy Buildings: Lessons Learned from Early Adopters,", Johnson Controls Institute for Building Efficiency. March 2012.

[7] RetrofitDepot, Rocky Mountain Institute, www.retrofitdepot.org

Decision-Making Criteria and the Value Beyond Energy Savings

A net zero retrofit project will have budget restrictions within which the design team must work, the same as any other retrofit project. To counterbalance the initial investment, project planners should consider the additional value net zero will provide beyond the energy cost savings. Those benefits may include:

1. Savings in water, maintenance, insurance and other building costs
2. Improved individual occupant satisfaction, health and productivity
3. Improved reputation and leadership of occupant enterprises
4. Enhanced energy security – providing the ability to continue operations in the event of a prolonged energy outage
5. Enhanced investor, customer, and regulator relations – reducing compliance costs and protecting and enhancing occupant revenues
6. Reduced risks of property economic and functional obsolescence and reduced enterprise risk for owner-occupants
7. Increased tenant and investor demand (for investor-owned properties) – and related improved occupancies, rents, tenant retention and other property revenues

These elements, also known as the Value Beyond Energy Cost Savings (VBECS), can be substantial. The scale of cost and benefit can be significant:

- Studies in the U.S. have found that green buildings have rental rates higher by 2 to 17 percent and resale value improved by 6 to 35 percent as compared to conventional buildings.[8]
- Studies have also demonstrated that green buildings may have health benefits due to better ventilation, lighting and general environment. Those benefits have been shown to increase worker productivity.[9]
- New models for calculating and presenting the value of retrofits beyond energy costs are emerging. They are based on traditional analytic approaches and valuation concepts consistent with existing practice.[10]

STEP 2: CHOOSING A DEFINITION OF NZE: WEIGHING DEFINITION TRADEOFFS

All net zero energy buildings share a goal of maximizing energy efficiency and then meeting remaining power needs with renewable energy. The key difference between types of net zero energy buildings is how and where the renewable energy is generated. The National Renewable Energy Laboratory has four well-defined and widely adopted definitions of net zero energy (Figure 2). All four definitions account for annual operations, even if there are surpluses and deficits on any single day or night, and are typically trued up annually. Net zero site energy is the most commonly used definition, and most in line with the spirit and intentions of achieving net zero. Each of the definitions has trade-offs regarding cost and tracking metrics,

[8] "Multiple Studies Document Green Buildings Add Value," Johnson Controls Institute for Building Efficiency.

[9] Loftness, et al. "Linking energy to health and productivity in the built environment." Center for Building Performance and diagnostics, Carnegie Mellon, 2003; Miller et al. "Green Buildings and Productivity." The Journal of Sustainable Real Estate, Vol. 1, No. 1, 2009; Kats, G. "The Costs and Benefits of green." A report to California's sustainable building task force. Capital e Analytics, October 2003.

[10] The Rocky Mountain Institute's Value Beyond Energy Cost Project is developing Retrofit Valuation Models for Occupants and Investors that provide clear linkages between energy efficiency measures, property outcomes and value and provide specific guidance on the calculation and presentation of VBECS to capital providers. In combination with work from the Appraisal Institute, Appraisal Foundation, the Department of Energy, the Institute for Market Transformation, and the Royal Institute of Chartered Surveyors, among others, significant progress in sustainable valuation is expected in the coming years.

and different types of renewable energy can be used to meet each definition.[11] The definitions could also be used in combination if a project team so desires. For example, a building could be both net zero site energy and net zero emissions.

Figure 2: Summary of definitions and tradeoffs for Net Zero Energy.[12]

Definition	Summary	Metric	Pros	Cons
Net zero *site* energy	Renewable energy must be generated on the building or site.	Site kBtu	· Simple accounting · Low external fluctuations (i.e., not dependent on energy prices)	· Annual energy bills may not be $0 · Assumes electricity exported from the site can be used to offset natural gas needs on site · May emphasize an all-electric strategy if PV is the primary renewable energy source
Net zero *source* energy	Energy use is accounted for at the source, including the energy used for extraction, generation and distribution.	Source kBtu	· More accurate depiction of total environmental impact	· Annual energy bills may not be $0 · More complex accounting (acquiring site-to-source conversion multipliers, source energy technology changes)
Net zero *cost* energy	The amount the owner pays the utility for the energy is less than or equal to the amount of money the utility pays the building owner for the renewable energy the building exports to the grid.	Dollars	· Energy costs are $0 · Simple accounting	
Net zero *emissions* energy	The building offsets all of the greenhouse gas emissions produced from the energy it uses through renewable energy production and carbon offsets (for up to 50% of net energy consumption).[13]	CO_2e	· Uses greenhouse gas metric that aligns with carbon disclosure efforts and climate change	· Annual energy bills may not be $0 · Challenging to track · Questions/concerns regarding carbon offsets

[11] Pless and Torcellini, "Net-Zero Energy Buildings: A classification System Based on Renewable Energy Supply Options," National Renewable Energy Laboratory, June 2010. Torcellini and Pless, "Defining Net Zero Energy Buildings," Building Design and Construction, March 2011.

[12] Torcellini et al, "Zero Energy Buildings: A Critical Look at the Definition" National Renewable Energy Laboratory, June 2006. Carlisle et at, "Definition of a 'Zero Net Energy' Community" National Renewable Energy Laboratory, 2009.

[13] "ASHRAE Vision 2020: Producing Net Zero Energy Buildings", January 2008.

STEP 3: SET A BASELINE AND DOCUMENT BUSINESS-AS-USUAL EXPENDITURES

At the onset of a project, the project team should clearly document the energy use, costs, and how the building is performing today, then lay out the anticipated future costs or the business-as-usual scenario without any net zero energy investments.[14] Under business as usual, there will be costs involved in operations, maintenance, repair and replacement that should be documented. The business-as-usual case should include estimates for anticipated end-of-life capital investment needs in addition to anticipated future energy costs. Knowing future costs under the business-as-usual scenario is critical for comparison with the future costs of operating and maintaining a net zero energy building. The project team can then build a comprehensive and compelling business case in which investments in energy efficiency can reduce loads to the point where mechanical equipment can be downsized or eliminated, reducing capital and operating expenses.

[14] RetrofitDepot, Rocky Mountain Institute, www.retrofitdepot.org

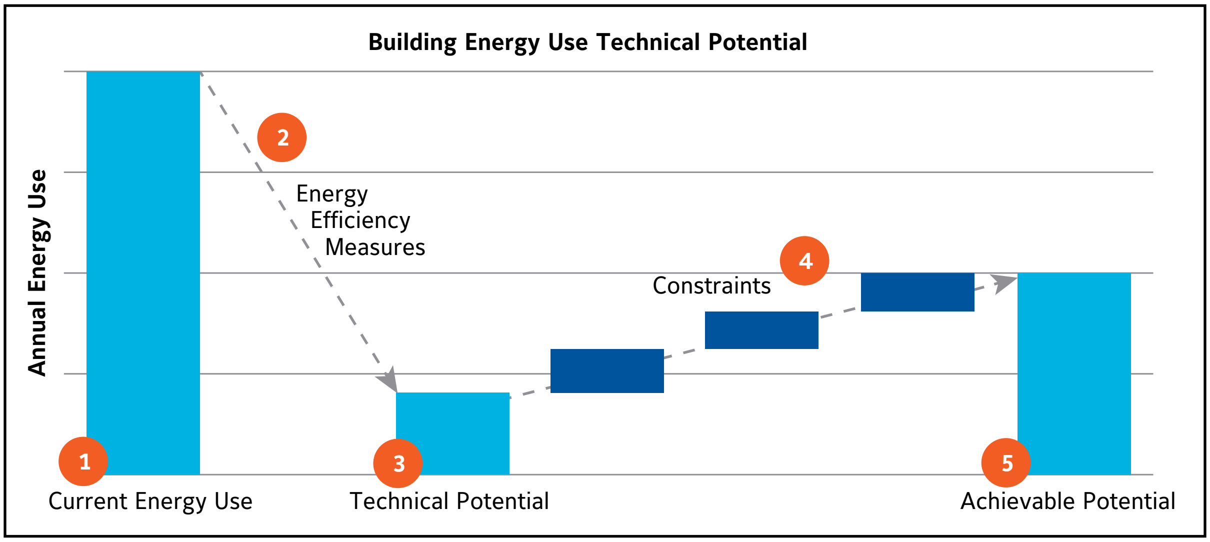
Often, this process is compiled using a typical baseline of consumption and costs and then applying an escalator using NIST guidance for energy costs and the Consumer Price Index for labor-related costs. Establishing a realistic baseline is critical in understanding and defining the life-cycle costs (or business-as-usual costs).

STEP 4: TECHNICAL POTENTIAL CHARRETTE

Every net zero energy project should start with a team charrette or brainstorming session to identify the technical potential for the building – the lowest possible energy use that could be provided by efficiency using available technology and best practices. This approach pushes engineers to focus on major, whole-systems improvements, fundamentally changing the design question from "We can't do this because ..." to "We could do this if..." It gets participants to think outside the box about options for maximizing the efficiency of each building system, about the types of on-site generation options that may be available, and about the ways different strategies interact to form an integrated design.

The following chart shows the flow in a typical technical potential charrette and subsequent analysis. It starts with the building's current energy use. Participants then brainstorm an exhaustive list of measures (potentially up to 70) that could bring the building energy use down to its technical potential. Recognizing that it is neither feasible nor cost-effective to implement them all, the team then puts forth the critical constraints that may impede their process. This is an important point at which to differentiate between real constraints and perceived constraints. For instance, it may be possible to work with the utility to get a different rate structure that could make a technology like thermal storage cost-effective, when previously it was disregarded as too expensive. The team then proceeds through integrative energy analysis to arrive at the achievable potential.

Figure 3: Technical potential process



Workshops are crucial to generating innovative and integrated design ideas, and they also provide an opportunity to engage key stakeholders and decision-makers early in the net zero project process. Keeping all key players engaged in the process is vital, and so is documenting decisions made along the way, so that resistance from decision-makers can be mitigated.

STEP 5: ITERATIVE MODELING, DESIGN, AND COSTING OF MEASURES

An energy model of the building is critical to selecting a compatible bundle of energy measures. Since many retrofit projects occur over multiple years, if the model is set up early, it can be calibrated based on actual building energy meters and updated on an ongoing basis. Each individual energy measure, as well as different combinations of measures, can be modeled to see how they affect load throughout the day, season, and year. The energy model should also be used to analyze the cost-effectiveness of different measures because in that event, investments in complementary measures can be analyzed together. For example, additional insulation may make it possible to install a smaller and lower-cost boiler, potentially adding up to a lower total cost. The optimal combination of energy measures, including the type of renewable energy generation, can then be selected based on project goals.

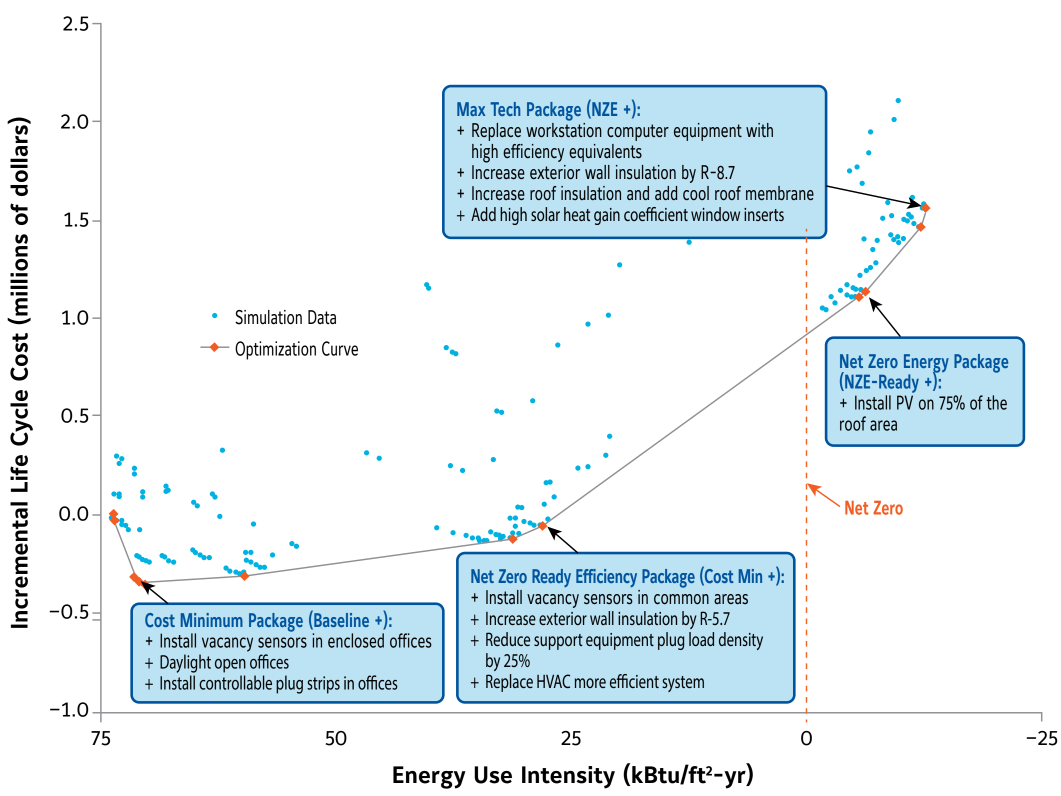
It is also critical to model and analyze savings from occupant engagement, since one quarter of energy use can be attributed to occupant behavior – from turning lights on and off, to the use of supplementary equipment.

Case Study: Ft. Carson[15]

The Army base at Ft. Carson is targeting aggressive energy efficiency to meet the goals of net zero energy, water and waste by 2020. As part of the net zero planning process for one building, an NREL team modeled the existing building geometry, layout, envelope, energy use, schedules and systems. The team then brainstormed a list of candidate measures for the retrofit, including improvements to the lighting, HVAC, envelope, plug loads, and renewable installations of PV. An Energy Simulation Optimization was completed in OpenStudio to optimize bundles of measures on both total life-cycle cost and energy use. As energy use decreases, the model solves mathematically for the bundle of efficiency and renewable generation measures that results in the lowest total life-cycle cost (highest net present value). The red dots represent packages of efficiency measures that are the most cost- effective combinations for various cost points. This type of analysis is critical to identifying the package of efficiency and renewable generation measures that will achieve net zero energy most cost-effectively.

A few other lessons can be extracted from the graph below. First, the Net Zero Ready Efficiency Package shows that significant efficiency can be gained at no additional cost. Often, this aggressive level of efficiency is overlooked until it is essential to the project, as in the case of net zero. Second, due to the high incremental cost of the renewable energy, there could be reasons for this owner to consider other PV financing mechanisms, such as a power purchase agreement, rather than purchasing the PV directly. That being said, the cost of PV has changed significantly over the past five years and will continue to decrease in the near future. It is also highly variable based on local utility rates and available incentives and rebates.

Building Optimization Analysis:



[15] Based on a presentation: Matt Leach, Bob Hendron, Shanti Pless, "NREL Support of LEED Demonstration Project: Net Zero Retrofit Optimization using OpenStudio". National Renewable Energy Laboratory. March 2013.

Several resources suggest specific measures and technologies to get to net zero, including the National Renewable Energy Lab studies, the Rocky Mountain Institute's recent book, *Reinventing Fire*, or the New Buildings Institute net zero studies and resources. It is important to remember that achieving significant energy reduction requires climate- and building-specific strategies and bundles of measures rather than individual technologies. These resources can help inform analysis, but design is not prescriptive.

Additional technical net zero considerations include:

a. Weighing the levelized costs between efficiency and renewables: Which efficiency measures save as much or more energy than it would cost to install renewables to offset that same energy use?

b. Net metering, load leveling and matching generation: What technologies can help decrease peaks in energy demand? What renewable technologies can be deployed to coincide with building demands?

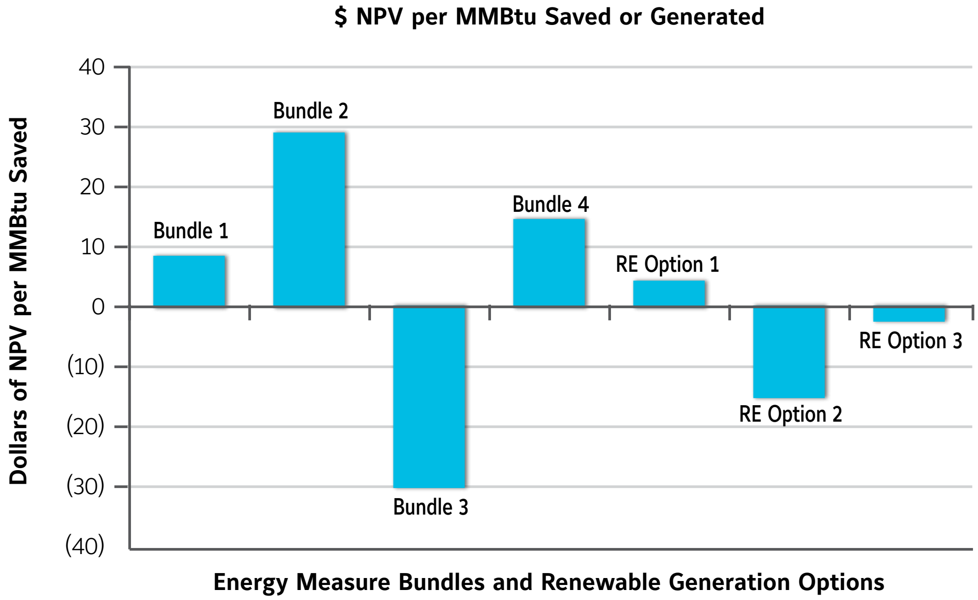
STEP 5, A: WEIGHING THE LEVELIZED COSTS BETWEEN EFFICIENCY AND RENEWABLES

One of the most important design decisions for net zero energy is to weigh the costs of efficiency against the cost of renewables, rather than the traditional method of having an external point of cost-effectiveness, such as simple payback, internal rate of return (IRR) or return on investment (ROI). The costs should be based on the life-cycle net present value (NPV), which should take into account operations and maintenance costs and savings, incentives and rebates, utility cost escalation, the potential cost of carbon, and the VBECS. For example, the capital expenditures for a green roof will be lower over time because the roof can be replaced every 50 instead of every 20 years.

A whole-building energy model working in conjunction with a life-cycle cost analysis model is absolutely necessary. It enables costs and savings to be accurately modeled against a business-as-usual base case (i.e., the cost of doing nothing) and with a carefully applied engineering touch it applies bundles of energy efficiency measures to identify the optimal package for energy and cost savings. Most important, energy/life-cycle cost analysis can alert design teams to the point at which efficiency measures become less cost-effective than renewable generation.

The NPV should be calculated not just for individual energy efficiency measures but for bundles of complementary measures. For example, the savings from installing a smaller chiller in a better-insulated building will be captured together. In addition, increased investment in energy efficiency to reduce total and peak demands can reduce the amount of renewable energy needed. But there comes a cost inflection point: Invest in energy efficiency up to the point where doing so costs as much as or more than installing or purchasing renewable energy generation. That sets the energy efficiency target before layering on the renewables. Figure 4 illustrates this principle. It also shows that on a life-cycle basis, energy efficiency (shown in bundles) is generally more cost-effective than renewable generation (show as RE Options). In this case, Bundle 2 and RE Option 1 are the most life-cycle cost-effective, even though they may carry the highest up-front costs.

Figure 4: Sample analysis of the net present value of bundles of efficiency measures (showing energy saved) compared to renewable energy technologies (showing energy generated) as analyzed for a sample project.



The accuracy and reliability of the NPV analysis depends on the quality and consistency of data inputs from a range of data sources, including the engineer, energy modeler and cost analyst, who all have background data from other parties (e.g. solar prices from the vendor, energy measures from the facility manager, cost estimates from the cost estimator). Care should be taken to integrate the timing and base assumptions used for each of these distinct analyses, since all the information is needed in order to make the decision. Any analysis gaps will skew the results. The best way to simplify this process is to bring all information points together for perhaps a week or two of intense interaction and modeling among a core team that understands the broad scope of the project. The investment in this time together will be well worth the effort, saving hours of backtracking and weeks of correspondence.

Case Study: NREL Net Zero Campus

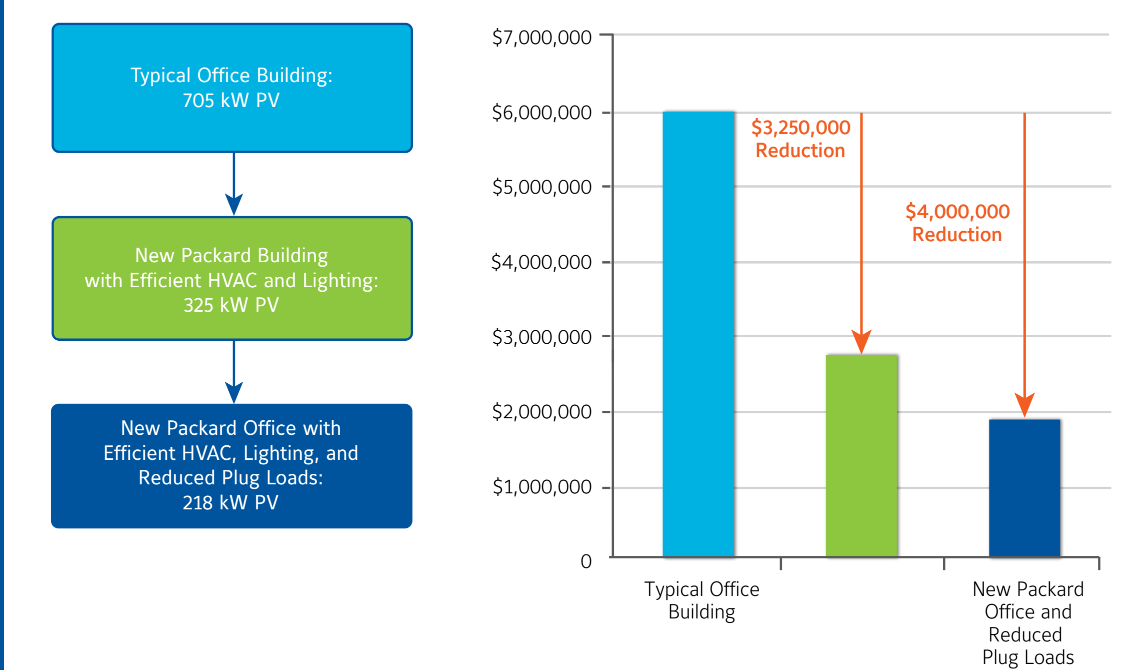
At the NREL Campus, a team evaluated the cost of all energy efficiency opportunities compared to the cost of PV. They found that every one continuous watt saved could avoid $33 of PV needed to offset that one watt. Therefore, any efficiency measure that cost less than the $33 per watt saved was implemented. Conversely, any efficiency measure that cost more than $33 per watt was abandoned and PV was used. This price threshold for each watt saved drove decisions, such as the purchase of new phones. NREL saved $375,000 in PV by going from a 15-watt phone to a 2-watt phone on everyone's desk. The resulting energy use per occupant is 283 watts, equivalent to four 70-watt incandescent light bulbs per occupant operating continuously. To achieve net zero energy, $8,500 of PV was required per occupant to offset occupant energy use.[16]

[16] Presentation: Chad Lobato, "Reducing Plug and Process Loads in NREL's Research Support Facility". April 2010.

Case Study: Packard Building

The Packard building is a 50,000-square-foot two-story office building completed in 2010. The following diagram about the project illustrates the principle of efficiency gains offsetting the need for additional PV. By implementing efficiency measures such as efficient lighting, HVAC and reduced plug load that cost $900,000, the project team reduced the amount of PV needed by $4 million, resulting in a first-cost savings of $3.1 million.

Energy Efficiency Offsets Need for PV [17]



[17] Presentation: Peter Rumsey, "Advanced Low Energy Buildings", Integral Group. August 2012.

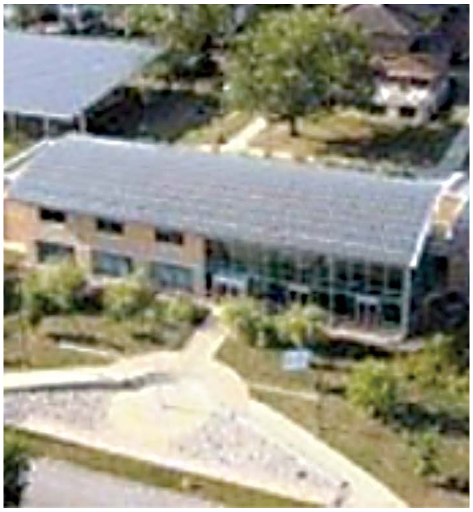
STEP 5, B: NET METERING, LOAD LEVELING AND MATCHING GENERATION

It should be determined early whether the utility serving the net zero facility allows net metering, as this will significantly affect the economics of a net zero building. In net metering, the utility agrees to buy back excess electricity generated at times when the building does not need it. Net metering is required in almost all states, but policies vary widely, the main differentiators being whether and how long a user can keep banked credits, and whether the credits are being bought back at the retail rate (what customers see on the bill), or the wholesale rate (the cost of the power to the utility).[18]

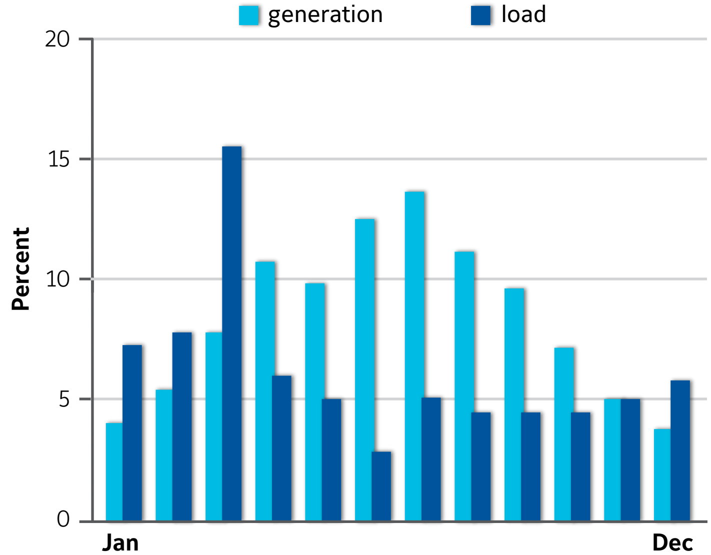
[18] For more information on Net Metering, refer to www.dsireusa.org.

While the total amount of energy required from the grid is less than for a typical building due to efficiency and on-site renewable generation, the demand profile changes substantially. On smaller time scales, such as hours, day and weeks, the amount of grid power that must be imported or exported could fluctuate considerably. The diagram below demonstrates the Oberlin College, Lewis Center load profiles, showing that the PV over-produces in summer and under-produces in winter.

Figure 5: Example of load profiles and the demand on the utility – even for net zero buildings.[19]



Oberlin College Lewis Center, Ohio



Load leveling, or balancing out a building's energy use, is an important strategy to avoid dramatic spikes in energy use (and cost), due to air conditioning needs and lighting and occupancy changes. It becomes paramount when a campus or group of buildings is generating its own on-site base load capacity, using renewables such as biomass. Energy modeling will help identify peaks and test strategies to load-level. From a utility perspective, load leveling can help reduce the need for potentially inefficient and high-emissions peaking plants.[20] This strategy will become increasingly important for all net zero energy projects as more time-of-use utility rate structures are put into place and as more net zero projects get on the grid, presenting utilities with more erratic energy profiles.

For all net zero energy projects, it is far more cost-effective to optimize energy efficiency first, and then carefully select and size renewable energy technologies that can accommodate both the peaks and valleys of the remaining loads. Figure 6 outlines some of the options to cover peaks.

[19] Voss et al, "Sustainable Zero Net Energy – Identifying the Essentials for Solutions,"Rocky Mountain Institute, PG&E. 2010. Graz et al, "Load Matching and Grid Interaction of Net Zero Energy Buildings," Proceedings of EuroSun, 2010.

[20] Salom et al, "Understanding Net Zero Energy Buildings: Evaluation of Load Matching and Grid Interaction Indicators," Proceedings of Building Simulation, 2011.

Figure 6: Load leveling strategies and renewable generation options.[21]

	Nighttime peaks in use or cost	Daytime peaks in use or cost
On-site renewable energy generation options	Low-impact hydro Wind (with nighttime peaks) Biofuels (Campus-scale projects. Includes biomass, wood pellets, ethanol or biodiesel)	Solar PV Solar hot hater Wind (with daytime peaks)
Load-shifting strategies to coincide with generation	Active thermal storage for mechanical systems (e.g., ice storage, chilled water storage) Passive thermal storage (e.g., building mass, phase-change materials) Nighttime computer backups District energy systems (Campus-scale projects. Combining commercial uses with daytime peak with residential evening/night peaks)	Daytime cleaning Daytime computer back-ups

In addition to addressing load leveling with on-site renewable energy generation and load-shifting strategies, load leveling using on-site battery storage should be considered in projects where energy security is a priority. Because it will continue to rely on the grid, the net zero energy building will be susceptible to grid blackouts just like any other. While electrical energy storage may not be a viable option at all sites, effective technologies are available for supplying power in the event of an interruption in supply from the grid.

STEP 6: PHASING INSTALLATION AND IMPLEMENTATION

A net zero project in an existing building can be implemented all at once or in stages. If the project is implemented in stages, it is still important to have an integrated perspective and a clear plan for when each of the selected energy measures is to be completed. The energy efficiency measures must be implemented first so that renewable technology can be appropriately sized for the final energy demand. For instance, while installing a new super-insulated roof, brackets could be flashed, even if PV is not installed immediately. Conduit chases should be installed and space for batteries or inverters set aside.

Any solutions should also consider the ability to adapt to future energy use increases or decreases. For instance, a biomass plant should be located in an area with ample space to add boilers as needed. Conversely, the biomass supplier must have the capability to increase or reduce supply as needed (such as for a school that has different occupancies during summer and winter).

A variety of financing and execution methods are available to net zero retrofits, including energy savings performance contracting (ESPCs), which can also be applied to new construction), the managed energy services agreement (MESA) model, property assessed clean energy (PACE), on-bill financing, and power purchase agreements (PPAs).[22]

[21] Pless and Torcellini, "Net-Zero Energy Buildings: A classification System Based on Renewable Energy Supply Options," National Renewable Energy Laboratory, June 2010.

[22] For more information, visit "U.S. Building Energy Efficiency Retrofits," Rockefeller Foundation and DB Climate Change Advisors, March 2012. "Innovations and Opportunities in Energy Efficiency Finance," Wilson, Sonsini, Goodrich & Rosati, May 2012. "Financing Models for Energy Efficiency and Renewable Energy in Existing Buildings" Johnson Controls Institute for Building Efficiency, September 2010.

STEP 7: PUBLICITY (INTERNAL AND EXTERNAL)

Once a building has achieved net zero status, the owner and any tenants can publicize that fact internally and externally, improving employee morale and the company's public image. Creating and communicating a compelling vision around the net zero energy building and process helps to ensure buy-in from stakeholders, especially the building's users. Occupants who become "green champions" can help buildings meet their net zero energy objectives.[23]

[23] "The Move Towards Net Zero Energy Buildings: Lessons Learned from Early Adopters," Johnson Controls Institute for Building Efficiency, March 2012.

STEP 8: ONGOING SYSTEM COMMISSIONING AND OCCUPANT BEHAVIOR

Once the net zero energy project is complete, it is not possible to "set it and forget it." It is essential to make the transition from design to operational performance. Facility managers and occupants must work together to make net zero energy a reality.

Facility management staff needs to be trained to operate the building. Ongoing monitoring and commissioning of building systems is key to ensuring that the building operates as initially designed. Management processes such as ISO 50001 should be established that support the building's energy performance.

Occupants should be engaged in the transition to net zero energy. Occupant behavior is particularly critical in a net zero energy building, since plug loads are usually the largest component of energy use. Designating internal champions, using educational dashboards, and setting up friendly "How low can you go?" competitions can help keep energy use down. Purchasing processes should mandate energy efficient computers, printers, appliances and other items that affect plug load. Leasing of key equipment, such as printers and phones, can help in staying current with technology improvements and energy reductions. During the first six months to a year into net zero operation, occupants will require extra feedback to know where the gaps are (e.g. lights are being left on at night).

CONCLUSION

Net zero energy is the bullseye for buildings wanting to stand out in today's market; it is the leading-edge level of achievement in energy performance and quality. While there were fewer than 50 commercial net zero buildings in operation in early 2013 (based on information available), there were many more in the design and construction stages. (There are also many small off-grid buildings with solar, wind and other renewable energy sources that are not traditionally thought of as adhering to the grid-connected net zero definitions). The case to go the distance is becoming more and more compelling, often driven by the desire to differentiate a building in the market. Occupants and tenants are asking for it. Good designers are fully capable of creating it. Smart owners and occupants are improving the business case to financially support it. And as efficiency and renewable technologies continue to improve and costs continue to decrease, net zero is certainly within reach. This set of process-driven considerations will make the decision simple, the implementation exciting and the results worth sharing.

ACKNOWLEDGEMENTS:

Thank you to the following people who contributed their time and energy to our research by reviewing our paper and providing directional advice during our research. The views contained in this analysis are those of the authors alone and are not necessarily shared by individuals or organizations listed here. A special thanks to Shanti Pless at NREL for providing input for our case studies.

Clay Nesler, Johnson Controls

Gerry Place, Johnson Controls

Hillary Price, Integral Group

Jennifer Layke, Johnson Controls

John Reasoner, Johnson Controls

Kinga Porst, General Services Administration

Mathias Bell, Rocky Mountain Institute

Michael Bendewald, Rocky Mountain Institute

Paul Schwer, PAE Engineers

Peter Bronski, Rocky Mountain Institute

Philip Macey, JE Dunn Construction

Scott Muldavin, Green Building Finance Consortium

Shanti Pless, National Renewable Energy Laboratory

Steve Spanbauer, Johnson Controls

Tom Hootman, RNL Design

Rocky Mountain Institute (RMI) is an independent, entrepreneurial, nonprofit think-and-do tank. RMI emphasizes integrative design, advanced technologies, and mindful markets in fulfilling its mission to drive the efficient and restorative use of resources. RMI's strategic focus is to map and drive the U.S. transition from fossil fuels to efficiency and renewables by 2050.

The Institute for Building Efficiency is an initiative of Johnson Controls providing information and analysis of technologies, policies, and practices for efficient, high performance buildings and smart energy systems around the world. The Institute leverages the company's 125 years of global experience providing energy efficient solutions for buildings to support and complement the efforts of nonprofit organizations and industry associations. The Institute focuses on practical solutions that are innovative, cost-effective and scalable.

If you are interested in contacting the authors, or engaging with the Institute for Building Efficiency, please email us at: InstituteforBE@jci.com.

 444 North Capitol St., NW Suite 729, Washington DC 20001 Printed in USA
www.johnsoncontrols.com